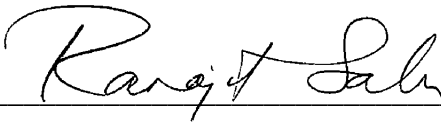


**NO<sub>x</sub> BART DETERMINATION COMMENTS**  
**FOR**  
**GREAT RIVER ENERGY (GRE) COAL CREEK STATION UNITS 1 AND 2**

**EXPERT REPORT**  
**OF**  
**DR. RANAJIT (RON) SAHU**



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**ON BEHALF OF THE**  
**NATIONAL PARKS CONSERVATION ASSOCIATION**

OCTOBER 30, 2012

## **Professional Background**

I have more than twenty-one years of experience in the fields of environmental, mechanical, and chemical engineering including: program and project management services; design and specification of pollution control equipment; soils and groundwater remediation; combustion engineering evaluations; energy studies; multimedia environmental regulatory compliance (involving statutes and regulations such as the Federal CAA and its Amendments, Clean Water Act, TSCA, RCRA, CERCLA, SARA, OSHA, NEPA as well as various related state statutes); transportation air quality impact analysis; multimedia compliance audits; multimedia permitting (including air quality NSR/PSD permitting, Title V permitting, NPDES permitting for industrial and storm water discharges, RCRA permitting, etc.), multimedia/multi-pathway human health risk assessments for toxics; air dispersion modeling; and regulatory strategy development and support including negotiation of consent agreements and orders.

I have more than nineteen years of project management experience and have successfully managed and executed numerous projects in this time period. This includes basic and applied research projects, design projects, regulatory compliance projects, permitting projects, energy studies, risk assessment projects, and projects involving the communication of environmental data and information to the public. Notably, I have successfully managed a complex soils and groundwater remediation project with a value of over \$140 million involving soils characterization, development and implementation of the remediation strategy, regulatory and public interactions and other challenges.

I have provided consulting services to numerous private sector, public sector and public interest group clients. My major clients over the past seventeen years include various steel mills, petroleum refineries, cement companies, aerospace companies, power generation facilities, lawn and garden equipment manufacturers, spa manufacturers, chemical distribution facilities, and various entities in the public sector including EPA, the U.S. Dept. of Justice, various states, and various municipalities, among others. I have performed projects in more than 44 states, numerous local jurisdictions and internationally.

Specifically for cement plants, I have provided air quality consulting and permitting services for numerous cement plants in the US since roughly 1995. I have assisted various plant owners and

operators as well as governmental agencies such as the EPA/DoJ in addressing compliance and non-compliance issues.

In addition to consulting, I have taught numerous courses in several Southern California universities including UCLA (air pollution), UC Riverside (air pollution, process hazard analysis), and Loyola Marymount University (air pollution, risk assessment, hazardous waste management) for the past seventeen years. In this time period I have also taught at Caltech, my alma mater, and at USC (air pollution) and Cal State Fullerton (transportation and air quality).

I have and continue to provide expert witness services in a number of environmental areas discussed above in both state and Federal courts, as well as before administrative bodies (please see Attachment A).

Additional details regarding my background and experience can be found in my resume provided in Attachment A which also includes a list of publications and presentations.

## **Introduction and Summary of Report**

Recently, as part of the North Dakota Regional Haze State Implementation Plan (SIP), the North Dakota Department of Health (NDDH) has finalized its proposal for NO<sub>x</sub> Best Available Retrofit Technology (BART) for Coal Creek Station (CCS) Units 1 and 2. A history of this determination is provided in the document titled “Supplemental Evaluation of NO<sub>x</sub> BART Determination for Coal Creek Station Units 1 and 2, NDDH, September 2012” (hereafter “Supplemental Evaluation”) available at <http://www.ndhealth.gov/AQ/RegionalHaze/>. As it had previously done, in its March 2010 SIP, the NDDH is proposing that the NO<sub>x</sub> BART for CCS Unit 1 and CCS Unit 2 be a limit of 0.17 lb/MMBtu (30 day rolling average basis), to be achieved at each unit based on combustion controls. These combustion controls include a technology called DryFining, which as discussed in the Supplemental Evaluation is employed at CCS Units 1 and 2, as well as the use of low NO<sub>x</sub> burners and over-fire air.

In determining that the BART limit should be 0.17 lb/MMBtu at each unit, the NDDH specifically rejected the use of the add-on NO<sub>x</sub> control technology called Selective Non-Catalytic Reduction (SNCR), suggested by the EPA. In this report, I will discuss why the NDDH’s BART determinations are incorrect, and specifically, why its rationale and stated reasons for the rejection of SNCR is incorrect. In doing so, I will rely on the Supplemental Evaluation as well as other documents provided by Great River Energy (GRE), the owner of CCS and its consultants. All of the documents that I rely on in this regard are available at the aforementioned website. In addition, as I rely on other documents or data, I will provide appropriate citations via footnotes.

As the NDDH has done in its Supplemental Evaluation, my comments are also organized by topic, following the same sequence as provided in the Supplemental Evaluation.

## Comments on Baseline NO<sub>x</sub> Emissions

For the reasons stated in the Supplemental Evaluation, the NDDH believes, per GRE, that the baseline NO<sub>x</sub> emissions of 5080 tons/yr for Unit 1 and 5086 tons/yr for Unit 2 are “reasonable.” Briefly, NDDH states that

“Based on the information provided by GRE, a baseline emission rate based on 0.201 lb/106 Btu at each unit is appropriate. For purposes of determining the annual emissions, the last five years of data (2006 – 2010) were reviewed. Based on the average of the highest two years in the last five years, the baseline heat input was as follows:

Unit 1 =  $5.0433 \times 10^{13}$  Btu/hr

Unit 2 =  $4.7965 \times 10^{13}$  Btu/hr

The calculated baseline emissions are:

E (Unit 1) =  $(5.0433 \times 10^{13} \text{ Btu/yr}) (0.201 \text{ lb/106 Btu}) \div (2000 \text{ lb/ton})$

E (Unit 1) = 5,069 tons/yr

E (Unit 2) =  $(4.7965 \times 10^{13} \text{ Btu/hr}) (0.201 \text{ lb/106 Btu}) \div (2000 \text{ lb/ton})$

E (Unit 2) = 4,820 tons/yr

GRE established their baseline emissions at 5,080 tons per year for Unit 1 and 5,086 tons per year for Unit 2. GRE’s estimate of baseline emissions appears to be reasonable.”<sup>1</sup>

Thus, NDDH’s (and GRE’s) determination of the baseline at each unit rests on two numbers – the highest annual heat input in the baseline period (2006-2010) and the NO<sub>x</sub> rate of 0.201 lb/MMBtu. I will examine both. In order to do so, I use data provided by GRE for CCS to the EPA available at EPA’s Acid Rain database ([www.epa.gov/ampd](http://www.epa.gov/ampd)). I have summarized this data, in monthly fashion in Attachment B.

As to heat input, it is clear from Attachment B that the highest annual heat input during the baseline period, using the same metric as used by NDDH (namely the “average of the highest two years in the last five years”) shows that the heat inputs are significantly greater than that determined by the NDDH. They are as follows:

For Unit 1, 51,969,572 MMBtu/yr (instead of NDDH’s  $5.0433 \times 10^{13}$  or 50,433,000 MMBtu/yr)

For Unit 2, 50,882,663 MMBtu/yr (instead of NDDH’s 47,965,000 MMBtu/yr)

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<sup>1</sup> Supplemental Evaluation, p. 5.

Since the NDDH does not provide any backup calculations, I am not sure as to why they have lower numbers in this regard.

Turning to the NO<sub>x</sub> rate, the NDDH has accepted that the NO<sub>x</sub> emission rate at each unit should be 0.201 lb/MMBtu, which, according to GRE and the NDDH is the emission rate after installation of DryFining at Unit 1. As the NDDH explains, it is appropriate to consider Unit 1's NO<sub>x</sub> emissions since it includes the effects of DryFining but not the effects of a separate low NO<sub>x</sub> technology called LNC3+ which has now been installed at Unit 2. Thus, NDDH asked GRE that it determine the "with-DryFining" rate for Unit 1 for use at both Units.

Without getting into the merits of whether or not even the inclusion of DryFining in the baseline determination is appropriate, I will show that, even with the inclusion of DryFining, the selection of 0.201 lb/MMBtu is not supportable. Again, I turn to Attachment B, using the data for Unit 1.

First, I note that DryFining was installed at both units in late 2009 and was operational starting in 2010. This was publicly reported. For example, an article in Power Engineering noted that "The DryFining systems on both units at Coal Creek have been in continuous service since completing their 24-hour commercialization runs in December 2009."<sup>2</sup> Thus, I have reviewed the NO<sub>x</sub> data for the time period after 2010 and through the present (i.e., through September of 2012, the most recent data available) to determine the NO<sub>x</sub> rate. As the calculations in Attachment B show, the maximum monthly NO<sub>x</sub> rate for 2010-Sept 2012 is 0.2309 lb/MMBtu; further, the annual averages were 0.210, 0.204, and 0.208 for 2010, 2011, and 2012 year-to-date. Thus, the use of 0.201 lb/MMBtu to denote the highest baseline is inappropriate and not supportable.

In fact, using the correct heat inputs and a conservative rate of 0.208 lb/MMBtu which is the average of the annual averages listed above, I obtain the following baseline NO<sub>x</sub> emission rates:

For Unit 1, 51,969,572 MMBtu/yr x 0.208 lb/MMBtu/2000 lb/ton = 5404 tons/yr

For Unit 2, 50,882,663 MMBtu/yr x 0.208 lb/MMBtu/2000 lb/ton = 5292 tons/yr,

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<sup>2</sup>Bullinger, C., et. al., An On-Site Process for Removing Moisture from Low-Rank Coal, Power Engineering, April 2010. Available at <http://www.power-eng.com/articles/print/volume-114/issue-4/Features/an-on-site-process-for-removing-moisture-from-low-rank-coal.html>. Exhibit 1a.

Of course the emissions would be even greater if I had used the maximum rate of 0.2309 lb/MMBtu.

In any case, the data do not support that implementation of DryFining would maintain a consistent NO<sub>x</sub> emission rate of 0.201 lb/MMBtu, as assumed by GRE and NDDH.

Thus, it is plain that both GRE's assumed baseline and NDDH's acceptance of GRE's baseline are incorrect. In each case, the baseline's used by GRE and NDDH significantly understate the actual appropriate baseline that should have been used in the analysis. For Unit 1, the baseline used (5080 tons/yr) is approximately 6% lower than the correct baseline of 5404 tons/yr. For Unit 2, the baseline used (5086 tons/yr) is approximately 4% lower.

The implication of using a lower baseline is that the benefits of using SNCR, as I will discuss later below are understated, leading to both lower visibility benefits and higher cost-effectiveness for SNCR. Since the NDDH has relied on both of these factors for rejecting SNCR, this error in the baseline calculation makes NDDH's rejection inappropriate, all other factors remaining the same.

However, as I discuss below, there are additional problems with NDDH's analysis.

## Comments on SNCR Control Efficiency

As the NDDH summarizes,

“GRE estimated that the control efficiency of SNCR after the installation of LNC3+ will be 20%. EPA estimated that 25% control efficiency can be attained (77 FR 20919). GRE’s estimate is based on a site-specific evaluation by URS. EPA’s estimate is based on data from facilities other than Coal Creek Station included in the Control Cost Manual and information from Fuel Tech, Inc. and the Institute of Clean Air Companies (ICAC).

“As part of the revised BART analysis, GRE supplied an EPRI report titled ‘Low-Baseline NOx Selective Non-Catalytic Reduction Demonstration’. The report documents the results of SNCR testing at Electric Energy’s Joppa Unit 3.”<sup>3</sup>

After brief discussion, the Supplemental Evaluation states that:

“The Department believes the URS estimate of 20% removal is credible and reasonable for the following reasons:

- 1) The EPRI report on low ( $\leq 88$  ppm) uncontrolled NOx emission rates indicates substantially less than 25% removal. With LNC3+, the NOx emission rate at Coal Creek Station will be approximately 88 ppm.
- 2) The URS estimate was based on a site specific evaluation of Coal Creek Station. EPA’s estimate was not.
- 3) The Control Cost Manual indicates SNCR will have a lower efficiency for boilers greater than  $3,000 \times 10^6$  Btu/hr heat (CCS boilers are approximately  $6,000 \times 10^6$  Btu/hr).”<sup>4</sup>

I have reviewed the SNCR analysis provided by URS. It is located in Appendix B of the “Coal Creek Station Units 1 and 2, Supplemental Best Available Retrofit Technology, Refined Analysis for NOx Emissions, November 2011; Updated April 5, 2012” provided by Barr Engineering on behalf of GRE to the NDDH. This document is also available on the aforementioned NDDH website.

First, URS’s SNCR experience is quite limited. In fact, Appendix B lists all of URS’s SNCR experience in a couple of tables. There are no projects for which URS did engineering work shown after 1998 (AES Warrior Run). Including any kind of work, such as feasibility studies, the latest project shown in 2002 (NRG, 5 stations, unspecified). Thus, EPA’s observation in the FIP (at 121-124) that URS is not an SNCR vendor is correct and apt. While URS is a large engineering firm, SNCR experience is specialized and NDDH, faced with the aging experience list provided by URS,

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<sup>3</sup> Supplemental Evaluation, p. 5.

<sup>4</sup> Supplemental Evaluation, p. 6.

should have conducted further due diligence as to current capabilities for SNCR. If it had done so, a good place to start would have been discussions with one of the leading vendors for SNCR in the US and worldwide, namely FuelTech. Not only would NDDH have obtained a better idea regarding SNCR efficiency using current implementation of SNCR technology, it would also have been able to obtain better cost and performance (i.e., ammonia slip) data, both of which are germane to a proper analysis of SNCR.

As I will show, in relying on URS information and the older Joppa Unit 3 report, NDDH has completely missed several recent advancements in SNCR. As a result, NDDH's rejection of SNCR is based on outdated, old, technical information.

Even though URS is not an SNCR vendor, it is well known, and even URS admits that SNCR performance is site-specific. In fact, in its SNCR memo, URS notes that "...SNCR performance is dependent upon factors that are specific to each source. These factors are; flue gas temperature, flue gas residence time at temperatures within the reaction temperature range, reagent distribution, uncontrolled NO<sub>x</sub> levels, mixing between the injected reagent and the flue gas, and the CO and O<sub>2</sub> concentrations in the flue gas stream." I agree. However, having said so, none of these site-specific factors are evaluated by URS in its SNCR memo. In reality, this evaluation is often done by the SNCR vendor, such as FuelTech. Thus, NDDH's stated reason #2 above that URS's estimate of control efficiency was based on a site-specific evaluation is simply untrue. Further, given the site specific nature of this evaluation, NDDH's stated reason #1 (i.e., reliance on Joppa) is also irrelevant. I also note that the Joppa Unit 3 testing was conducted in November 2008<sup>5</sup> which predated several advancements in SNCR technology as I will discuss below. Of course, NDDH's stated reason #3 above is so weak that it deserves no comment; nonetheless, I note that the technology has evolved since that portion of the Cost Control Manual was written and the actual efficiency will be dependent on site specific factors as noted above.

Had NDDH (or even URS) conducted even the most cursory evaluation of the current state-of-the-art SNCR, it would have found (and reported) that in order to obtain better mixing of the reagent (ammonia) and the exhaust gases, which has the effect of improving control efficiency and minimizing ammonia slip, FuelTech currently uses a technology called High Energy Reagent

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<sup>5</sup> Low-Baseline NO<sub>x</sub> Selective Non-Catalytic Reduction Demonstration Joppa Unit 3, EPRI Report 1018665, March 2009, p. 3-1. Available at <http://www.ndhealth.gov/AQ/RegionalHaze/>.

Technology Injection or HERT. HERT is specifically designed for high energy, low momentum injectors to achieve low ammonia slip.<sup>6</sup> In fact, FuelTech describes “[R]ecent applications with low baseline and control levels at or below 0.1 lb/MMBtu....”<sup>7</sup> FuelTech acquired this technology around 2010 and it was well-known even prior. That the URS memo on SNCR, written well after this date (the Barr report was updated as recently as April 2012), makes no mention of HERT shows its irrelevance.

In view of this, it is my opinion that a proper evaluation of SNCR, including costs and ammonia slip, cannot be complete without a thorough evaluation of the NO<sub>x</sub> reduction that can be obtained using HERT, on a site-specific basis. This can only be done with further discussions directly with the technology vendor, Fuel Tech. Only GRE and/or NDDH can have this discussion since they are in a position to provide the site access and engineering details needed for this evaluation. Rejecting SNCR without this analysis (and including the results in the public docket) is premature and hasty.

It is my opinion that unless shown otherwise, based on the discussion above, a NO<sub>x</sub> rate of 0.1 lb/MMBtu using HERT should be assumed (along with DryFining and/or LNC3+) for SNCR, along with an ammonia slip of between 2-5 ppm. It should be GRE’s burden to provide technical support as to why this level cannot be achieved.

Using the same baseline NO<sub>x</sub> levels that I have calculated above, and keeping the heat inputs constant as in the baseline period, the NO<sub>x</sub> reductions that SNCR/HERT would provide are as follows:

For Unit 1, 51,969,572 MMBtu/yr x (0.208– 0.10) lb/MMBtu/2000 lb/ton = 2806 tons/yr.

For Unit 2, 50,882,663 MMBtu/yr x (0.208– 0.10) lb/MMBtu/2000 lb/ton = 2748tons/yr.

Thus, all further analyses, including, critically, the cost-effectiveness and the visibility impacts analyses should be redone, using these reductions. Since the current analyses assume far smaller NO<sub>x</sub> reductions for each unit, for this reason alone, neither the visibility impacts analysis, nor the

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<sup>6</sup>SNCR – NO<sub>x</sub>OUT and HERT Processes, FuelTech. Available at <http://www.ftek.com/en-US/products/apc/noxout/>. Exhibit 1b.

<sup>7</sup> Dougherty, K., SNCR Operation Workshop, Reinhold NO<sub>x</sub> Roundtable Conference, February 2011. Available at [http://www.ftek.com/media/en-US/ppts/Reinhold\\_2011\\_KD.pdf](http://www.ftek.com/media/en-US/ppts/Reinhold_2011_KD.pdf). Exhibit 1c.

cost-effectiveness analysis is correct. The visibility benefits as currently calculated are understated and the cost-effectiveness values calculated currently are over-stated.

In addition, the cost-effectiveness analysis presented by GRE and accepted by NDDH is additionally impaired by erroneous considerations of the capital cost of SNCR, which I discuss next.

## Comments on Capital Cost of SNCR

In the Supplemental Evaluation, NDDH states the following:

“GRE has estimated the Installed Capital Cost (Total Capital Investment) for SNCR to be \$12.18 million dollars for each unit. EPA has estimated that the capital cost to be \$5,374,000 (76 FR 58620, Table 57). GRE’s (URS) estimate is based on a site specific evaluation made by URS and URS software developed from actual projects. EPA’s estimate uses GRE’s estimate for direct capital cost and the remaining factors in the Control Cost Manual for SNCR (77 FR 58620). The major difference between the two cost estimates is a 1.6 retrofit factor used by GRE, but disallowed by EPA.”<sup>8</sup> “With a retrofit factor of 1.0 (no increase for a retrofit), the IPM methodology predicts a cost that is about double EPA’s estimated cost. With a retrofit factor of 1.6, the IPM estimates a cost that is about 5% higher than GRE’s estimate. The GRE estimate using a 1.6 retrofit factor is within 30% of the IPM estimate with a retrofit factor of 1.0.....[A]djusting the cost to 2011 dollars using the Consumer Price Index yields a cost range of \$12 - \$34 per kilowatt. GRE’s estimate is approximately \$20 per kilowatt (2011 dollars). EPA’s estimate is approximately \$9 per kilowatt (2009 dollars) or approximately \$9.4 per kilowatt in the 2011 dollars.”<sup>9</sup>

NDDH then summarizes as follows:

“Based upon its review and consideration, the Department believes GRE’s capital cost estimate is credible and reasonable for the following reasons:

- 1) EPA’s estimate is based on the Control Cost Manual which is out-of-date.
- 2) Cost estimates using the IPM and EPA’s Fact Sheet for SNCR suggests GRE’s estimate is accurate ( $\pm 30\%$ ).
- 3) The GRE estimate is a site specific estimate as suggested by the BART Guidelines. EPA’s estimate is not site specific.”<sup>10</sup>

The gist of NDDH’s argument regarding cost is that the URS estimate is based on a “site-specific” evaluation, that it relies on “software developed from actual projects” and must therefore be superior.

First, I reiterate URS’s lack of experience with SNCR projects - with no stated projects in roughly 10 years. Second, I expose URS’s lack of SNCR experience by showing that it is either unaware or did not choose to report on relevant recent developments such as HERT. Third, I have reviewed the URS SNCR memorandum in terms of how the capital cost estimate was developed and find no

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<sup>8</sup> Supplemental Evaluation, p. 7.

<sup>9</sup> Supplemental Evaluation, p. 8.

<sup>10</sup> Supplemental Evaluation, p. 8.

support that it uses “site-specific” information. Perhaps NDDH believes that because URS staff may have visited the site, therefore the estimate is deemed “site-specific.” If so, it is naïve.

Let us examine the estimate itself. For ease of reference, I have pasted below the entirety of URS’s capital cost estimate (for 5 different cases) from its SNCR memorandum.

**Table 3 – Material Costs**

<b>SNCR Material Costs</b>		0.22 Inlet & 30% Reduction	0.20 Inlet & 25% Reduction	0.16 Inlet & 20% Reduction	0.15 Inlet & 20% Reduction	0.22 & 50% Reduction
Cost Basis Year		2011	2011	2011	2011	2011
SNCR Equipment Cost	\$	\$3,800,000	\$3,700,000	\$3,600,000	\$3,600,000	\$4,200,000
Installation Factor		1.30	1.30	1.30	1.30	1.30
Installed Equipment Cost	\$	\$4,970,000	\$4,800,000	\$4,700,000	\$4,700,000	\$5,500,000
Prime Contractor's Markup	\$	\$497,000	\$480,000	\$470,000	\$470,000	\$550,000
Total Installed Cost	\$	\$5,500,000	\$5,300,000	\$5,100,000	\$5,100,000	\$6,000,000
Retrofit Factor		1.6	1.6	1.6	1.6	1.6
Total Equipment Cost	\$	\$8,750,000	\$8,500,000	\$8,200,000	\$8,200,000	\$9,600,000
General Facilities	\$	\$440,000	\$420,000	\$410,000	\$410,000	\$480,000
Engineering Fees	\$	\$875,000	\$850,000	\$820,000	\$820,000	\$960,000
Process Contingencies	\$	\$503,000	\$488,000	\$472,000	\$472,000	\$553,000
Project Contingencies	\$	\$1,580,000	\$1,540,000	\$1,490,000	\$1,490,000	\$1,740,000
Total Plant Cost (TPC)	\$	\$12,145,000	\$11,790,000	\$11,420,000	\$11,400,000	\$13,350,000
Total Cash Expended (TCE)	\$	\$12,145,000	\$11,790,000	\$11,420,000	\$11,400,000	\$13,350,000
Allowance for Funds During Construc	\$	0	0	0	0	0
Total Plant Investment (TPI)	\$	\$12,145,000	\$11,790,000	\$11,420,000	\$11,400,000	\$13,350,000
Preproduction Costs	\$	\$243,000	\$236,000	\$228,000	\$227,000	\$267,000
Inventory Capital	\$	\$167,000	\$134,000	\$100,000	\$98,000	\$260,000
Initial Catalyst and Chemicals	\$	\$0	\$0	\$0	\$0	\$0
Prepaid Royalties	\$	\$44,000	\$42,000	\$41,000	\$41,000	\$48,000
Total Capital Requirement (TCR)	\$	\$12,600,000	\$12,200,000	\$11,600,000	\$11,600,000	\$13,900,000
Market Demand Escalation	\$	\$0	\$0	\$0	\$0	\$0
Power Outage Penalty	\$	\$0	\$0	\$0	\$0	\$0
Land Cost	\$	\$0	\$0	\$0	\$0	\$0
TCR w/ Market Dem., Power Outage	\$	\$12,600,000	\$12,200,000	\$11,600,000	\$11,600,000	\$13,900,000
\$/kW		21.80	21.10	20.40	20.40	24.00
Mills/kWh		0.40	0.38	0.37	0.37	0.44

Let us consider the “0.20 inlet & 25% Reduction” case, since it is the most relevant to the discussion based on the inlet value of 0.201 considered by NDDH.

First, there is simply no support or information for the basic assumption that the “SNCR Equipment Cost” is 3.7 million dollars. No vendor specifications or vendor quotes are provided. How this relates to any site-specific consideration is a mystery. NDDH should explain the basis of this fundamental cost line item.

Second, URS uses an “installation factor” of 1.3 on top of the 3.7 million dollars above, to arrive at an Installed Equipment Cost of 4.8 million dollars. The basis for the 1.3 or 30% factor and its scope is also a mystery since URS provides no support for this whatsoever.

Third, on top of the line items above, and neglecting the unsupported “Prime Contractor Markup,” URS then adds on a multiplier of 1.6 for “Retrofit Factor.” While it is expected that costs in a retrofit situation may be higher than a new construction, the choice of a retrofit factor should be based on site-specific details showing why costs would, in fact, be greater. But, here again, URS provides no support. In fact, the entire record contains not a shred of engineering support for this 1.6 retrofit factor. Yet, NDDH accepts it as fact. NDDH is mistaken. In fact, some of the most complex SCR projects (which involve far more equipment, ductwork rearrangements, fan upgrades, etc.) conducted by numerous coal plants in the last several years have retrofit factors that are far smaller. To use a blatantly high factor such as 1.6 with no support merely exposes and reinforces the idea that URS simply has little credibility with regards to SNCR. It is simply a transparent attempt to drive up the estimated cost, only to ensure rejection of the technology.

But the cost estimate is not done yet. Notwithstanding the inclusion of every conceivable contingency that should already be covered by the three items above, URS also added separate “Process Contingency” and “Project Contingency” line items – and these two alone are over 2 million dollars. Of course, URS does not explain why there should be any process contingency for an old technology such as SNCR or why one needs a substantial “project contingency” on top of an already inflated retrofit factor and installation factor.

That NDDH chose to accept this cost estimate (and chose to characterize it as being “site-specific”) boggles the mind. In fact, rationally, a site-specific estimate would not have so many unspecific and unsupported factors and contingencies, since they would have been narrowed down relying on site-specific facts. That the estimate uses these unsupported factors and contingencies makes the estimate, by definition, not site specific.

The same sort of reliance on inappropriate and unsupported factors is also present in the most recent cost-estimates of SNCR provide by GRE. I have excerpted one of these below.

BART Supplement - NO<sub>x</sub> Emission Control Cost AnalysisTable A-5: Unit 1 NO<sub>x</sub> Control - Selective Non-Catalytic Reduction SNCR Lignite Coal (Maintain Ash Sales)

## CAPITAL COSTS

Direct Capital Costs		
Purchased Equipment		3,700,000
Purchased Equipment Costs		
Instrumentation	10% of purchased equipment cost	370,000
Site Specific and Prime Contractor Markup	28% of purchased equipment cost	1,036,000
Freight	5% of purchased equipment cost	185,000
Purchased Equipment Total	43%	5,291,000
Purchased Equipment Total+ Retrofit Factor (A)		8,465,600
Indirect Installation		
General Facilities	See Notes & Assumptions 1 on pg. 1 of Table	420,000
Engineering & Home Office	See Notes & Assumptions 1 on pg. 1 of Table	850,000
Process Contingency	See Notes & Assumptions 1 on pg. 1 of Table	488,000
Total Indirect Installation Costs (B)	See Notes & Assumptions 1 on pg. 1 of Table	1,758,000
Project Contingency (C)	See Notes & Assumptions 1 on pg. 1 of Table	1,540,000
Total Plant Cost (D)	A + B + C	11,763,600
Allowance for Funds During Construction (E)	0 for SNCR	0
Prepaid Royalties (F)	See Notes & Assumptions 1 and 7 on pg. 1 of Table	42,000
Pre Production Costs (G)	See Notes & Assumptions 1 on pg. 1 of Table	236,000

Again, there is no support for the purchased equipment cost of 3.7 million at the beginning. Also, there is no support for the 10% instrumentation markup or the 28% “site-specific” markup and of course, the retrofit factor. As noted earlier, this estimate also contains the additional process and project contingencies.

Even with all of these “adjustments” the URS cost estimate is \$21.1/kW. Let us compare this with typical SNCR costs, as provided by Fuel Tech, an actual vendor. In a recent SEC filing, Fuel Tech notes that “Fuel Tech’s NO<sub>x</sub>OUT and HERT SNCR processes use non-hazardous urea as the reagent rather than ammonia. Both the NO<sub>x</sub>OUT and HERT processes on their own are capable of reducing NO<sub>x</sub> by up to 25% — 50% for utilities and by potentially significantly greater amounts for industrial units in many types of plants with capital costs ranging from \$5 — \$20/kW for utility boilers....”<sup>11</sup> This is instructive. URS’s estimate is at or greater than the high range of Fuel Tech’s estimate. In fact, given the size of the CCS units (i.e., over 600 MW), one would expect that they should have costs that are at the low-end of the \$/kW cost range, given the economies of scale, not to mention the further economies afforded by sharing common equipment between the two units. In fact, EPA’s estimate, which NDDH notes is \$9.4/kW, is just about right, per Fuel Tech.

<sup>11</sup> [http://www.faqs.org/sec-filings/100304/FUEL-TECH-INC\\_10-K/](http://www.faqs.org/sec-filings/100304/FUEL-TECH-INC_10-K/). Exhibit 1d.

Thus, the NDDH acceptance of these cost estimates has no basis. NDDH, in order to preserve its own credibility, should obtain a proper cost estimate from a vendor instead of relying on the GRE/Barr/URS “estimates” above.

Finally, NDDH’s reason for setting aside the EPA estimate – namely that it is out of date would have had more credibility had it, in fact, reviewed GRE’s cost basis for many items. Again, I have excerpted Table A-3 from GRE’s most recent submittal to the NDDH. It is instructive to examine the “Data Sources” column in this table. In fact, many of the line items reference the very same EPA Control Cost Manual that NDDH deems out of date. Thus, NDDH’s reasoning simply is flawed.

Great River Energy Coal Creek Station  
BART Supplement - NOx Emission Control Cost Analysis  
Table A-3: Summary of Utility, Chemical and Supply Costs

Technical Update 06/07/2012

Operating Unit:	Unit 1 or 2	Study Year	2011		
From Golder Report					
Item	Unit Cost	Units	Reference Cost	Year	Data Source
Operating Labor	37.00	\$/hr	25.86	2002	Stone & Webster 2002 Cost Estimate; confirmed by GRE
Maintenance Labor	37.00	\$/hr	26.25	2002	Stone & Webster 2002 Cost Estimate; confirmed by GRE
Electricity	0.0604	\$/kwh	0.049	2004	DOE Average Retail Price of Industrial Electricity, 2004 <a href="http://www.eia.doe.gov/emeu/aer/txt/ptb0810.html">http://www.eia.doe.gov/emeu/aer/txt/ptb0810.html</a>
Water	0.31	\$/kgal	0.79	2002	Stone & Webster 2002 Cost Estimate; confirmed by GRE
Cooling Water	0.32	\$/kgal	0.23	1999	EPA Air Pollution Control Cost Manual, 6th ed. Section 3.1 Ch 1
Compressed Air	0.37	\$/ksf	0.25	1998	EPA Air Pollution Control Cost Manual 6th Ed 2002, Section 6 Chapter 1
Wastewater Disposal Neutralization	1.96	\$/kgal	1.50	2002	EPA Air Pollution Control Cost Manual 6th Ed 2002, Section 2 Chapter 2.5.5.5
Wastewater Disposal Bio-Treat	4.96	\$/kgal	3.80	2002	EPA Air Pollution Control Cost Manual 6th Ed 2002, Section 5.2 Chapter 1
Solid Waste Disposal - No Impact	0.000	\$/ton	0.00	2011	Assume no change in GRE landfill cost for ash
Solid Waste Disposal - 30% Lost	5.438	\$/ton	5.438	2011	Golder Fly Ash Management Evaluation - Nov. 2011
Solid Waste Disposal - 100% Lost	7.396	\$/ton	7.396	2011	Golder Fly Ash Management Evaluation - Nov. 2011
Hazardous Waste Disposal	326.19	\$/ton	250.00	2002	EPA Air Pollution Control Cost Manual 6th Ed 2002, Section 2 Chapter 2.5.5.5
Waste Transport	0.65	\$/ton-mi	0.500	2002	EPA Air Pollution Control Cost Manual 6th Ed 2002, Section 6 Chapter 3
Ash Sales	12.300	\$/ton	12.300	2011	Golder Fly Ash Management Evaluation - Nov. 2011
Ammonia Mitigation	5.610	\$/ton	5.610	2011	Golder Fly Ash Management Evaluation - Nov. 2011
Chemicals & Supplies					
Lime	90.00	\$/ton	72.19	2005	GRE per Diane Stockdill 12/6/05 email
Caustic	364	\$/ton	305.21	2005	GRE per Diane Stockdill 12/6/05 email
Urea	500	\$/ton	500	2011	URS SNCR Report - November 2011
Oxygen	17.91	ksf	15.00	2005	Get cost from Air Prod Website
EPA Urea	179.1	\$/ton			
Ammonia	1	\$/lb	0.92	2005	GRE per Diane Stockdill
Other					
Sales Tax	0	%			GRE per Diane Stockdill 12/6/05 email
Interest Rate	5.50	%			GRE per Diane Stockdill 12/6/05 email
Please note, for units of measure, k = 1,000 units, MM = 1,000,000 units e.g. kgal = 1,000 gal					
Future Operating Scenario for BART Cost Analysis					
Operating Information	Unit 1	Unit 2			
Annual Op. Hrs	8,409.6	8,409.6	Hours		July 2010 to October 2011 Coal Creek Emission Data
Utilization Rate	100.0%	100.0%			GRE per Diane Stockdill 12/6/05 email
Equipment Life	20	20	Yrs		Engineering Estimate
Coal Ash	11.70	11.70	wt % ash		2010 Coal Creek Emission Inventory
Coal Sulfur	0.64	0.64	% Coal Sulfur Content		July 2010 to October 2011 Coal Creek Emission Data
Coal Heating Value	6,373	6,373	Btu/lb of coal		July 2010 to October 2011 Coal Creek Emission Data
Design Capacity	6,015	6,022	MMBtu/hr		
ID Fan Flow Rates	Assumes coal drying with DryFining™				
Standardized Flow Rate	866293.7	866293.7	scfm @ 329 F		
Temperature	330.0	330.0	Deg F		GRE per G. Riveland 4/5/06 email
Moisture Content	13.3%	13.3%			GRE per G. Riveland 4/5/06 email
Actual Flow Rate	2,234,300	2,234,300	acfm		GRE per G. Riveland 4/5/06 email
Standardized Flow Rate	1,391,000	1,391,000	scfm @ 330F		GRE per G. Riveland 4/5/06 email
Dry Std Flow Rate	1,205,997	1,205,997	dsfcm @ 330F		
NOx Pollutant Data					
Max Emiss (lb/hr)	1,208.1	1,209.5			Calculated using baseline emission rate and design capacities
Max Emiss (tpv)	5,079.9	5,085.8			Calculated
Baseline Emiss (lb/MMBtu)	0.201	0.201			Unit 1 average prior to LNC3+ installation

I also note that the IPM cost modeling that GRE did and that NDDH references also contains numerous non-site-specific assumptions. For example, the IPM models as calculated by GRE show that the SNCR cost is highly sensitive to retrofit factor assumption. For example, in the IPM runs presented by GRE, the base cost for SNCR (“BMS”) is 2.995 million with retrofit factor (RF)=1, 3.894 million with RF=1.3, and 4.788 million with RF=1.6. Yet, again, there is little or no justification for selection of the RF of 1.6 other than a footnote (FN5) to Table A-5 which states that “Retrofit factor of 60% used by URS based on site visit to Coal Creek Station...” Without documentation, it is not clear how URS determined the RF just by visiting or walking around the site.

Based on the above, I can only conclude that GRE’s SNCR cost estimate is inflated. A reasonable capital cost would likely be at the low end of the \$5-20/kW range. Given the inherent efficiency associated with installing two of these and therefore sharing in a substantial portion of the fixed costs, a reasonable capital cost may be in the \$9/kW or even lower range.

## Comments on Lost Ash Sales

Finally, NDDH and GRE provide extensive discussion on the likelihood of lost ash sales as a result of ammonia slip. And, as a result, the cost estimate is further inflated to account for both lost ash sales and ash disposal.

It is my opinion that this is entirely premature. As I have noted above, current SNCR/HERT technology is designed precisely to minimize ammonia slip. Thus, it is not reasonable to presume that ammonia slip will be high and therefore the costs of lost ash sales/ash disposal will be real.

Although there are several technologies that are being used to mitigate ammonia from fly-ash currently (including the one by Headwaters, that has been discussed in the record), I believe that a discussion of these options is also pre-mature, given that the underlying problem simply may not exist using SNCR/HERT.

Even though GRE's analysis considers a range of lost ash sales, NDDH provides no basis for its assumption that "...GRE expects a minimum of 30% lost ash sales and possibly 100% lost ash sales..."<sup>12</sup> The Golder report merely contains a sensitivity analysis of what the costs might be if there were various levels of lost ash sales. It does not contain any basis for what the actual lost ash sales may be. Nor can it, given that the cause of the ash contamination would be ammonia slip, a factor that is not within Golder's technical scope. Even Golder's report states that "Definitive information is not available for the levels of ammonia that could be present in the fly ash at CCS due to SNCR ammonia slip..." as the NDDH notes.<sup>13</sup>

It is also curious that GRE and Golder did not examine a case of 15% loss of ash sales, given GRE's own experience at the East Lake Station in Ohio. As the Supplemental Evaluation states, "GRE has reported that the East Lake Station in Ohio must treat or blend 85% of their ash to make it marketable because of ammonia contamination. Fifteen percent of the ash has highly variable ammonia concentrations due to SNCR upset or plant load swings. This 15% of the ash is unmarketable because of the high ash ammonia content."<sup>14</sup>

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<sup>12</sup> Supplemental Evaluation, p. 10.

<sup>13</sup> Supplemental Evaluation, p. 11.

<sup>14</sup> Supplemental Evaluation, p. 10.

In summary, on this issue, I reiterate that inclusion of any costs for loss of ash sales and/or ash disposal is premature without a careful examination of the low-ammonia slip SNCR advancements as represented by HERT.

## Conclusion

As I have discussed in this report, NDDH's proposal that the NO<sub>x</sub> BART for the CCS Units 1 and 2 be set without SNCR and at a level of 0.17 lb/MMBtu is not supported. NDDH has accepted, without examination or independent verification, GRE's flawed technical analysis. The baseline NO<sub>x</sub> levels are wrong and lower than they should be. The SNCR NO<sub>x</sub> reduction capability assumed is outdated and under-predicts what is achievable. Together, as I have shown, the NO<sub>x</sub> reduction that should be expected is much greater at each unit. That means that the visibility benefit when SNCR is used, as currently relied upon, is understated and would be much greater than assumed.<sup>15</sup> Thus, NDDH's rejection of SNCR due to low visibility benefits is unsupported.

In addition, as I have shown, SNCR capital costs have been over-estimated. Thus, the cost-effectiveness of SNCR (whether total or incremental) are overestimated as well. Again, rejection of SNCR on cost ground is therefore not supported.

Finally, the issue of loss of fly ash sales or ash disposal, is, at this stage, completely speculative.

Based on the above, it is my opinion that the NDDH evaluation does not constitute a thorough, technically competent evaluation of SNCR, as it is being implemented today, relying on vendors and consultants who have the requisite expertise.

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<sup>15</sup> I also note that the visibility modeling uses a CALPUFF option to use puff splitting, which is unusual – and this is likely further to reduce visibility benefits. Protocol for BART-Related Visibility Impairment Modeling Analyses in North Dakota (Final), November, 2005, North Dakota Department of Health. Table 3-5.

## **ATTACHMENT A – RESUME**

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### **EXPERIENCE SUMMARY**

Dr. Sahu has over twenty one years of experience in the fields of environmental, mechanical, and chemical engineering including: program and project management services; design and specification of pollution control equipment; soils and groundwater remediation; combustion engineering evaluations; energy studies; multimedia environmental regulatory compliance (involving statutes and regulations such as the Federal CAA and its Amendments, Clean Water Act, TSCA, RCRA, CERCLA, SARA, OSHA, NEPA as well as various related state statutes); transportation air quality impact analysis; multimedia compliance audits; multimedia permitting (including air quality NSR/PSD permitting, Title V permitting, NPDES permitting for industrial and storm water discharges, RCRA permitting, etc.), multimedia/multi-pathway human health risk assessments for toxics; air dispersion modeling; and regulatory strategy development and support including negotiation of consent agreements and orders.

He has over nineteen years of project management experience and has successfully managed and executed numerous projects in this time period. This includes basic and applied research projects, design projects, regulatory compliance projects, permitting projects, energy studies, risk assessment projects, and projects involving the communication of environmental data and information to the public. Notably, he has successfully managed a complex soils and groundwater remediation project with a value of over \$140 million involving soils characterization, development and implementation of the remediation strategy, regulatory and public interactions and other challenges.

He has provided consulting services to numerous private sector, public sector and public interest group clients. His major clients over the past seventeen years include various steel mills, petroleum refineries, cement companies, aerospace companies, power generation facilities, lawn and garden equipment manufacturers, spa manufacturers, chemical distribution facilities, and various entities in the public sector including EPA, the US Dept. of Justice, California DTSC, various municipalities, etc.). Dr. Sahu has performed projects in over 44 states, numerous local jurisdictions and internationally.

Dr. Sahu's experience includes various projects in relation to industrial waste water as well as storm water pollution compliance include obtaining appropriate permits (such as point source NPDES permits) as well development of plans, assessment of remediation technologies, development of monitoring reports, and regulatory interactions.

In addition to consulting, Dr. Sahu has taught numerous courses in several Southern California universities including UCLA (air pollution), UC Riverside (air pollution, process hazard analysis), and Loyola Marymount University (air pollution, risk assessment, hazardous waste management) for the past seventeen years. In this time period he has also taught at Caltech, his alma mater and at USC (air pollution) and Cal State Fullerton (transportation and air quality).

Dr. Sahu has and continues to provide expert witness services in a number of environmental areas discussed above in both state and Federal courts as well as before administrative bodies (please see Annex A).

### **EXPERIENCE RECORD**

2000-present **Independent Consultant.** Providing a variety of private sector (industrial companies, land development companies, law firms, etc.) public sector (such as the US Department of Justice) and

public interest group clients with project management, air quality consulting, waste remediation and management consulting, as well as regulatory and engineering support consulting services.

- 1995-2000 Parsons ES, **Associate, Senior Project Manager and Department Manager for Air Quality/Geosciences/Hazardous Waste Groups**, Pasadena. Responsible for the management of a group of approximately 24 air quality and environmental professionals, 15 geoscience, and 10 hazardous waste professionals providing full-service consulting, project management, regulatory compliance and A/E design assistance in all areas.
- Parsons ES, **Manager for Air Source Testing Services**. Responsible for the management of 8 individuals in the area of air source testing and air regulatory permitting projects located in Bakersfield, California.
- 1992-1995 Engineering-Science, Inc. **Principal Engineer and Senior Project Manager** in the air quality department. Responsibilities included multimedia regulatory compliance and permitting (including hazardous and nuclear materials), air pollution engineering (emissions from stationary and mobile sources, control of criteria and air toxics, dispersion modeling, risk assessment, visibility analysis, odor analysis), supervisory functions and project management.
- 1990-1992 Engineering-Science, Inc. **Principal Engineer and Project Manager** in the air quality department. Responsibilities included permitting, tracking regulatory issues, technical analysis, and supervisory functions on numerous air, water, and hazardous waste projects. Responsibilities also include client and agency interfacing, project cost and schedule control, and reporting to internal and external upper management regarding project status.
- 1989-1990 Kinetics Technology International, Corp. **Development Engineer**. Involved in thermal engineering R&D and project work related to low-NO<sub>x</sub> ceramic radiant burners, fired heater NO<sub>x</sub> reduction, SCR design, and fired heater retrofitting.
- 1988-1989 Heat Transfer Research, Inc. **Research Engineer**. Involved in the design of fired heaters, heat exchangers, air coolers, and other non-fired equipment. Also did research in the area of heat exchanger tube vibrations.

## **EDUCATION**

- 1984-1988 Ph.D., Mechanical Engineering, California Institute of Technology (Caltech), Pasadena, CA.
- 1984 M. S., Mechanical Engineering, Caltech, Pasadena, CA.
- 1978-1983 B. Tech (Honors), Mechanical Engineering, Indian Institute of Technology (IIT) Kharagpur, India

## **TEACHING EXPERIENCE**

### Caltech

"Thermodynamics," Teaching Assistant, California Institute of Technology, 1983, 1987.

"Air Pollution Control," Teaching Assistant, California Institute of Technology, 1985.

"Caltech Secondary and High School Saturday Program," - taught various mathematics (algebra through calculus) and science (physics and chemistry) courses to high school students, 1983-1989.

"Heat Transfer," - taught this course in the Fall and Winter terms of 1994-1995 in the Division of Engineering and Applied Science.

"Thermodynamics and Heat Transfer," Fall and Winter Terms of 1996-1997.

### U.C. Riverside, Extension

"Toxic and Hazardous Air Contaminants," University of California Extension Program, Riverside, California. Various years since 1992.

"Prevention and Management of Accidental Air Emissions," University of California Extension Program, Riverside, California. Various years since 1992.

"Air Pollution Control Systems and Strategies," University of California Extension Program, Riverside, California, Summer 1992-93, Summer 1993-1994.

"Air Pollution Calculations," University of California Extension Program, Riverside, California, Fall 1993-94, Winter 1993-94, Fall 1994-95.

"Process Safety Management," University of California Extension Program, Riverside, California. Various years since 1992-2010.

"Process Safety Management," University of California Extension Program, Riverside, California, at SCAQMD, Spring 1993-94.

"Advanced Hazard Analysis - A Special Course for LEPCs," University of California Extension Program, Riverside, California, taught at San Diego, California, Spring 1993-1994.

"Advanced Hazardous Waste Management" University of California Extension Program, Riverside, California. 2005.

#### LoyolaMarymountUniversity

"Fundamentals of Air Pollution - Regulations, Controls and Engineering," LoyolaMarymountUniversity, Dept. of Civil Engineering. Various years since 1993.

"Air Pollution Control," LoyolaMarymountUniversity, Dept. of Civil Engineering, Fall 1994.

"Environmental Risk Assessment," LoyolaMarymountUniversity, Dept. of Civil Engineering. Various years since 1998.

"Hazardous Waste Remediation" LoyolaMarymountUniversity, Dept. of Civil Engineering. Various years since 2006.

#### University of Southern California

"Air Pollution Controls," University of Southern California, Dept. of Civil Engineering, Fall 1993, Fall 1994.

"Air Pollution Fundamentals," University of Southern California, Dept. of Civil Engineering, Winter 1994.

#### University of California, Los Angeles

"Air Pollution Fundamentals," University of California, Los Angeles, Dept. of Civil and Environmental Engineering, Spring 1994, Spring 1999, Spring 2000, Spring 2003, Spring 2006, Spring 2007, Spring 2008, Spring 2009.

#### International Programs

"Environmental Planning and Management," 5 week program for visiting Chinese delegation, 1994.

"Environmental Planning and Management," 1 day program for visiting Russian delegation, 1995.

"Air Pollution Planning and Management," IEP, UCR, Spring 1996.

"Environmental Issues and Air Pollution," IEP, UCR, October 1996.

### **PROFESSIONAL AFFILIATIONS AND HONORS**

President of India Gold Medal, IIT Kharagpur, India, 1983.

Member of the Alternatives Assessment Committee of the Grand Canyon Visibility Transport Commission, established by the Clean Air Act Amendments of 1990, 1992-present.

American Society of Mechanical Engineers: Los Angeles Section Executive Committee, Heat Transfer Division, and Fuels and Combustion Technology Division, 1987-present.

Air and Waste Management Association, West Coast Section, 1989-present.

#### **PROFESSIONAL CERTIFICATIONS**

EIT, California (# XE088305), 1993.

REA I, California (#07438), 2000.

Certified Permitting Professional, South Coast AQMD (#C8320), since 1993.

QEP, Institute of Professional Environmental Practice, since 2000.

CEM, State of Nevada (#EM-1699). Expiration 10/07/2011.

#### **PUBLICATIONS (PARTIAL LIST)**

"Physical Properties and Oxidation Rates of Chars from Bituminous Coals," with Y.A. Levendis, R.C. Flagan and G.R. Gavalas, *Fuel*, **67**, 275-283 (1988).

"Char Combustion: Measurement and Analysis of Particle Temperature Histories," with R.C. Flagan, G.R. Gavalas and P.S. Northrop, *Comb. Sci. Tech.* **60**, 215-230 (1988).

"On the Combustion of Bituminous Coal Chars," PhD Thesis, California Institute of Technology (1988).

"Optical Pyrometry: A Powerful Tool for Coal Combustion Diagnostics," *J. Coal Quality*, **8**, 17-22 (1989).

"Post-Ignition Transients in the Combustion of Single Char Particles," with Y.A. Levendis, R.C. Flagan and G.R. Gavalas, *Fuel*, **68**, 849-855 (1989).

"A Model for Single Particle Combustion of Bituminous Coal Char." Proc. ASME National Heat Transfer Conference, Philadelphia, **HTD-Vol. 106**, 505-513 (1989).

"Discrete Simulation of Cenospheric Coal-Char Combustion," with R.C. Flagan and G.R. Gavalas, *Combust. Flame*, **77**, 337-346 (1989).

"Particle Measurements in Coal Combustion," with R.C. Flagan, in "**Combustion Measurements**" (ed. N. Chigier), Hemisphere Publishing Corp. (1991).

"Cross Linking in Pore Structures and Its Effect on Reactivity," with G.R. Gavalas in preparation.

"Natural Frequencies and Mode Shapes of Straight Tubes," Proprietary Report for Heat Transfer Research Institute, Alhambra, CA (1990).

"Optimal Tube Layouts for Kamui SL-Series Exchangers," with K. Ishihara, Proprietary Report for Kamui Company Limited, Tokyo, Japan (1990).

"HTRI Process Heater Conceptual Design," Proprietary Report for Heat Transfer Research Institute, Alhambra, CA (1990).

"Asymptotic Theory of Transonic Wind Tunnel Wall Interference," with N.D. Malmuth and others, Arnold Engineering Development Center, Air Force Systems Command, USAF (1990).

"Gas Radiation in a Fired Heater Convection Section," Proprietary Report for Heat Transfer Research Institute, College Station, TX (1990).

"Heat Transfer and Pressure Drop in NTIW Heat Exchangers," Proprietary Report for Heat Transfer Research Institute, College Station, TX (1991).

"NO<sub>x</sub> Control and Thermal Design," Thermal Engineering Tech Briefs, (1994).

"From Purchase of Landmark Environmental Insurance to Remediation: Case Study in Henderson, Nevada," with Robin E. Bain and Jill Quillin, presented at the AQMA Annual Meeting, Florida, 2001.

"The Jones Act Contribution to Global Warming, Acid Rain and Toxic Air Contaminants," with Charles W. Botsford, presented at the AQMA Annual Meeting, Florida, 2001.

## **PRESENTATIONS (PARTIAL LIST)**

"Pore Structure and Combustion Kinetics - Interpretation of Single Particle Temperature-Time Histories," with P.S. Northrop, R.C. Flagan and G.R. Gavalas, presented at the AIChE Annual Meeting, New York (1987).

"Measurement of Temperature-Time Histories of Burning Single Coal Char Particles," with R.C. Flagan, presented at the American Flame Research Committee Fall International Symposium, Pittsburgh, (1988).

"Physical Characterization of a Cenospheric Coal Char Burned at High Temperatures," with R.C. Flagan and G.R. Gavalas, presented at the Fall Meeting of the Western States Section of the Combustion Institute, Laguna Beach, California (1988).

"Control of Nitrogen Oxide Emissions in Gas Fired Heaters - The Retrofit Experience," with G. P. Croce and R. Patel, presented at the International Conference on Environmental Control of Combustion Processes (Jointly sponsored by the American Flame Research Committee and the Japan Flame Research Committee), Honolulu, Hawaii (1991).

"Air Toxics - Past, Present and the Future," presented at the Joint AIChE/AAEE Breakfast Meeting at the AIChE 1991 Annual Meeting, Los Angeles, California, November 17-22 (1991).

"Air Toxics Emissions and Risk Impacts from Automobiles Using Reformulated Gasolines," presented at the Third Annual Current Issues in Air Toxics Conference, Sacramento, California, November 9-10 (1992).

"Air Toxics from Mobile Sources," presented at the Environmental Health Sciences (ESE) Seminar Series, UCLA, Los Angeles, California, November 12, (1992).

"Kilns, Ovens, and Dryers - Present and Future," presented at the Gas Company Air Quality Permit Assistance Seminar, Industry Hills Sheraton, California, November 20, (1992).

"The Design and Implementation of Vehicle Scrapping Programs," presented at the 86th Annual Meeting of the Air and Waste Management Association, Denver, Colorado, June 12, 1993.

"Air Quality Planning and Control in Beijing, China," presented at the 87th Annual Meeting of the Air and Waste Management Association, Cincinnati, Ohio, June 19-24, 1994.

## Annex A

### Expert Litigation Support

#### **1. Matters for which Dr. Sahu has have provided depositions and affidavits/expert reports include:**

- (a) Deposition on behalf of Rocky Mountain Steel Mills, Inc. located in Pueblo, Colorado – dealing with the manufacture of steel in mini-mills including methods of air pollution control and BACT in steel mini-mills and opacity issues at this steel mini-mill
- (b) Affidavit for Rocky Mountain Steel Mills, Inc. located in Pueblo Colorado – dealing with the technical uncertainties associated with night-time opacity measurements in general and at this steel mini-mill.
- (c) Expert reports and depositions (2/28/2002 and 3/1/2002; 12/2/2003 and 12/3/2003; 5/24/2004) on behalf of the US Department of Justice in connection with the Ohio Edison NSR Cases. *United States, et al. v. Ohio Edison Co., et al.*, C2-99-1181 (S.D. Ohio).
- (d) Expert reports and depositions (5/23/2002 and 5/24/2002) on behalf of the US Department of Justice in connection with the Illinois Power NSR Case. *United States v. Illinois Power Co., et al.*, 99-833-MJR (S.D. Ill.).
- (e) Expert reports and depositions (11/25/2002 and 11/26/2002) on behalf of the US Department of Justice in connection with the Duke Power NSR Case. *United States, et al. v. Duke Energy Corp.*, 1:00-CV-1262 (M.D.N.C.).
- (f) Expert reports and depositions (10/6/2004 and 10/7/2004; 7/10/2006) on behalf of the US Department of Justice in connection with the American Electric Power NSR Cases. *United States, et al. v. American Electric Power Service Corp., et al.*, C2-99-1182, C2-99-1250 (S.D. Ohio).
- (g) Affidavit (March 2005) on behalf of the Minnesota Center for Environmental Advocacy and others in the matter of the Application of Heron Lake BioEnergy LLC to construct and operate an ethanol production facility – submitted to the Minnesota Pollution Control Agency.
- (h) Expert reports and depositions (10/31/2005 and 11/1/2005) on behalf of the US Department of Justice in connection with the East Kentucky Power Cooperative NSR Case. *United States v. East Kentucky Power Cooperative, Inc.*, 5:04-cv-00034-KSF (E.D. KY).
- (i) Deposition (10/20/2005) on behalf of the US Department of Justice in connection with the Cinergy NSR Case. *United States, et al. v. Cinergy Corp., et al.*, IP 99-1693-C-M/S (S.D. Ind.).
- (j) Affidavits and deposition on behalf of Basic Management Inc. (BMI) Companies in connection with the BMI vs. USA remediation cost recovery Case.
- (k) Expert report on behalf of Penn Future and others in the Cambria Coke plant permit challenge in Pennsylvania.
- (l) Expert report on behalf of the Appalachian Center for the Economy and the Environment and others in the Western Greenbrier permit challenge in West Virginia.
- (m) Expert report, deposition (via telephone on January 26, 2007) on behalf of various Montana petitioners (Citizens Awareness Network (CAN), Women's Voices for the Earth (WVE) and the Clark Fork Coalition (CFC)) in the Thompson River Cogeneration LLC Permit No. 3175-04 challenge.
- (n) Expert report and deposition (2/2/07) on behalf of the Texas Clean Air Cities Coalition at the Texas State Office of Administrative Hearings (SOAH) in the matter of the permit challenges to TXU Project Apollo's eight new proposed PRB-fired PC boilers located at seven TX sites.
- (o) Expert testimony (July 2007) on behalf of the Izaak Walton League of America and others in connection with the acquisition of power by Xcel Energy from the proposed Gascoyne Power Plant – at the State of Minnesota, Office of Administrative Hearings for the Minnesota PUC (MPUC No. E002/CN-06-1518; OAH No. 12-2500-17857-2).
- (p) Affidavit (July 2007) Comments on the Big Cajun I Draft Permit on behalf of the Sierra Club – submitted to the Louisiana DEQ.
- (q) Expert reports and deposition (12/13/2007) on behalf of Commonwealth of Pennsylvania – Dept. of Environmental Protection, State of Connecticut, State of New York, and State of New Jersey (Plaintiffs) in connection with the Allegheny Energy NSR Case. *Plaintiffs v. Allegheny Energy Inc., et al.*, 2:05cv0885 (W.D. Pennsylvania).

- (r) Expert reports and pre-filed testimony before the Utah Air Quality Board on behalf of Sierra Club in the Sevier Power Plant permit challenge.
- (s) Expert reports and deposition (October 2007) on behalf of MTD Products Inc., in connection with General Power Products, LLC v MTD Products Inc., 1:06 CVA 0143 (S.D. Ohio, Western Division)
- (t) Experts report and deposition (June 2008) on behalf of Sierra Club and others in the matter of permit challenges (Title V: 28.0801-29 and PSD: 28.0803-PSD) for the Big Stone II unit, proposed to be located near Milbank, South Dakota.
- (u) Expert reports, affidavit, and deposition (August 15, 2008) on behalf of Earthjustice in the matter of air permit challenge (CT-4631) for the Basin Electric Dry Fork station, under construction near Gillette, Wyoming before the Environmental Quality Council of the State of Wyoming.
- (v) Affidavits (May 2010/June 2010 in the Office of Administrative Hearings)/Declaration and Expert Report (November 2009 in the Office of Administrative Hearings) on behalf of NRDC and the Southern Environmental Law Center in the matter of the air permit challenge for Duke Cliffside Unit 6. Office of Administrative Hearing Matters 08 EHR 0771, 0835 and 0836 and 09 HER 3102, 3174, and 3176 (consolidated).
- (w) Declaration (August 2008), Expert Report (January 2009), and Declaration (May 2009) on behalf of Southern Alliance for Clean Energy et al., v Duke Energy Carolinas, LLC. in the matter of the air permit challenge for Duke Cliffside Unit 6. *Southern Alliance for Clean Energy et al., v. Duke Energy Carolinas, LLC*, Case No. 1:08-cv-00318-LHT-DLH (Western District of North Carolina, Asheville Division).
- (x) Dominion Wise County MACT Declaration (August 2008)
- (y) Expert Report on behalf of Sierra Club for the Green Energy Resource Recovery Project, MACT Analysis (June 13, 2008).
- (z) Expert Report on behalf of Sierra Club and the Environmental Integrity Project in the matter of the air permit challenge for NRG Limestone's proposed Unit 3 in Texas (February 2009).
- (aa) Expert Report and deposition on behalf of MTD Products, Inc., in the matter of Alice Holmes and Vernon Holmes v. Home Depot USA, Inc., et al. (June 2009, July 2009).
- (bb) Expert Report on behalf of Sierra Club and the Southern Environmental Law Center in the matter of the air permit challenge for Santee Cooper's proposed Pee Dee plant in South Carolina (August 2009).
- (cc) Statements (May 2008 and September 2009) on behalf of the Minnesota Center for Environmental Advocacy to the Minnesota Pollution Control Agency in the matter of the Minnesota Haze State Implementation Plans.
- (dd) Expert Report (August 2009) and Deposition (October 2009) on behalf of Environmental Defense, in the matter of permit challenges to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).
- (ee) Deposition (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed Coletto Creek coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH). (October 2009).
- (ff) Expert Report, Rebuttal Report (September 2009) and Deposition (October 2009) on behalf of the Sierra Club, in the matter of challenges to the proposed Medicine Bow Fuel and Power IGL plant in Cheyenne, Wyoming.
- (gg) Expert Report (December 2009), Rebuttal reports (May 2010 and June 2010) and depositions (June 2010) on behalf of the US Department of Justice in connection with the Alabama Power Company NSR Case. *United States v. Alabama Power Company*, CV-01-HS-152-S (Northern District of Alabama, Southern Division).
- (hh) Prefiled testimony (October 2009) and Deposition (December 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed White Stallion Energy Center coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).
- (ii) Deposition (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed Tenaska coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH). (April 2010).

- (jj) Written Direct Testimony (July 2010) and Written Rebuttal Testimony (August 2010) on behalf of the State of New Mexico Environment Department in the matter of Proposed Regulation 20.2.350 NMAC – *Greenhouse Gas Cap and Trade Provisions*, No. EIB 10-04 (R), to the State of New Mexico, Environmental Improvement Board.
- (kk) Expert report (August 2010) and Rebuttal Expert Report (October 2010) on behalf of the US Department of Justice in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana).
- (ll) Declaration (August 2010), Reply Declaration (November 2010), Expert Report (April 2011), Supplemental and Rebuttal Expert Report (July 2011) on behalf of the US EPA and US Department of Justice in the matter of DTE Energy Company and Detroit Edison Company (Monroe Unit 2). *United States of America v. DTE Energy Company and Detroit Edison Company*, Civil Action No. 2:10-cv-13101-BAF-RSW (US District Court for the Eastern District of Michigan).
- (mm) Expert Report and Deposition (August 2010) as well as Affidavit (September 2010) on behalf of Kentucky Waterways Alliance, Sierra Club, and Valley Watch in the matter of challenges to the NPDES permit issued for the Trimble County power plant by the Kentucky Energy and Environment Cabinet to Louisville Gas and Electric, File No. DOW-41106-047.
- (nn) Expert Report (August 2010), Rebuttal Expert Report (September 2010), Supplemental Expert Report (September 2011), and Declaration (November 2011) on behalf of Wild Earth Guardians in the matter of opacity exceedances and monitor downtime at the Public Service Company of Colorado (Xcel)’s Cherokee power plant. No. 09-cv-1862 (D. Colo.).
- (oo) Written Direct Expert Testimony (August 2010) and Affidavit (February 2012) on behalf of Fall-Line Alliance for a Clean Environment and others in the matter of the PSD Air Permit for Plant Washington issued by Georgia DNR at the Office of State Administrative Hearing, State of Georgia (OSAH-BNR-AQ-1031707-98-WALKER).
- (pp) Deposition (August 2010) on behalf of Environmental Defense, in the matter of the remanded permit challenge to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).
- (qq) Expert Report, Supplemental/Rebuttal Expert Report, and Declarations (October 2010) on behalf of New Mexico Environment Department (Plaintiff-Intervenor), Grand Canyon Trust and Sierra Club (Plaintiffs) in the matter of Public Service Company of New Mexico (PNM)’s Mercury Report for the San Juan Generating Station, CIVIL NO. 1:02-CV-0552 BB/ATC (ACE). US District Court for the District of New Mexico.
- (rr) Comment Report (October 2010) on the Draft Permit Issued by the Kansas DHE to Sunflower Electric for Holcomb Unit 2. Prepared on behalf of the Sierra Club and Earthjustice.
- (ss) Expert Report (October 2010) and Rebuttal Expert Report (November 2010) (BART Determinations for PSCo Hayden and CSU Martin Drake units) to the Colorado Air Quality Commission on behalf of Coalition of Environmental Organizations.
- (tt) Expert Report (November 2010) (BART Determinations for TriState Craig Units, CSU Nixon Unit, and PRPA Rawhide Unit) to the Colorado Air Quality Commission on behalf of Coalition of Environmental Organizations.
- (uu) Declaration (November 2010) on behalf of the Sierra Club in connection with the Martin Lake Station Units 1, 2, and 3. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Case No. 5:10-cv-00156-DF-CMC (US District Court for the Eastern District of Texas, Texarkana Division).
- (vv) Comment Report (December 2010) on the Pennsylvania Department of Environmental Protection (PADEP)’s Proposal to grant Plan Approval for the Wellington Green Energy Resource Recovery Facility on behalf of the Chesapeake Bay Foundation, Group Against Smog and Pollution (GASP), National Park Conservation Association (NPCA), and the Sierra Club.
- (ww) Written Expert Testimony (January 2011) and Declaration (February 2011) to the Georgia Office of State Administrative Hearings (OSAH) in the matter of Minor Source HAPs status for the proposed Longleaf Energy Associates power plant (OSAH-BNR-AQ-1115157-60-HOWELLS) on behalf of the Friends of the Chattahoochee and the Sierra Club).
- (xx) Declaration (February 2011) in the matter of the Draft Title V Permit for RRI Energy MidAtlantic Power Holdings LLC Shawville Generating Station (Pennsylvania), ID No. 17-00001 on behalf of the Sierra Club.

- (yy) ExpertReport (March 2011), RebuttalExpertReport (June 2011) on behalf of the United States in *United States of America v. Cemex, Inc.*, Civil Action No. 09-cv-00019-MSK-MEH (US District Court for the District of Colorado).
- (zz) Declaration (April 2011) in the matter of the Lower Colorado River Authority (LCRA)'s Fayette (Sam Seymour) Power Plant on behalf of the Texas Campaign for the Environment. *Texas Campaign for the Environment v. Lower Colorado River Authority*, Civil Action No. 4:11-cv-00791 (US District Court for the Southern District of Texas, Houston Division).
- (aaa) Declaration (June 2011) on behalf of the Plaintiffs MYTAPN in the matter of Microsoft-Yes, Toxic Air Pollution-No (MYTAPN) v. State of Washington, Department of Ecology and Microsoft Corporation Columbia Data Center to the Pollution Control Hearings Board, State of Washington, Matter No. PCHB No. 10-162.
- (bbb) Expert Report (June 2011) on behalf of the New Hampshire Sierra Club at the State of New Hampshire Public Utilities Commission, Docket No. 10-261 – the 2010 Least Cost Integrated Resource Plan (LCIRP) submitted by the Public Service Company of New Hampshire (re. Merrimack Station Units 1 and 2).
- (ccc) Declaration (August 2011) in the matter of the Sandy Creek Energy Associates L.P. Sandy Creek Power Plant on behalf of Sierra Club and Public Citizen. *Sierra Club, Inc. and Public Citizen, Inc. v. Sandy Creek Energy Associates, L.P.*, Civil Action No. A-08-CA-648-LY (US District Court for the Western District of Texas, Austin Division).
- (ddd) Expert Report (October 2011) on behalf of the Defendants in the matter of *John Quiles and Jeanette Quiles et al. v. Bradford-White Corporation, MTD Products, Inc., Kohler Co., et al.*, Case No. 3:10-cv-747 (TJM/DEP) (US District Court for the Northern District of New York).
- (eee) Declaration (February 2012) and Second Declaration (February 2012) in the matter of *Washington Environmental Council and Sierra Club Washington State Chapter v. Washington State Department of Ecology and Western States Petroleum Association*, Case No. 11-417-MJP (US District Court for the Western District of Washington).
- (fff) Expert Report (March 2012) in the matter of *Environment Texas Citizen Lobby, Inc and Sierra Club v. ExxonMobil Corporation et al.*, Civil Action No. 4:10-cv-4969 (US District Court for the Southern District of Texas, Houston Division).
- (ggg) Declaration (March 2012) in the matter of *Center for Biological Diversity, et al. v. United States Environmental Protection Agency*, Case No. 11-1101 (consolidated with 11-1285, 11-1328 and 11-1336) (US Court of Appeals for the District of Columbia Circuit).
- (hhh) Declaration (March 2012) in the matter of *Sierra Club v. The Kansas Department of Health and Environment*, Case No. 11-105,493-AS (Holcomb power plan) (Supreme Court of the State of Kansas).
- (iii) Declaration (March 2012) in the matter of the Las Brisas Energy Center *Environmental Defense Fund et al., v. Texas Commission on Environmental Quality*, Cause No. D-1-GN-11-001364 (District Court of Travis County, Texas, 261<sup>st</sup> Judicial District).
- (jjj) Expert Report (April 2012) in the matter of the Portland Power plant *State of New Jersey and State of Connecticut (Intervenor-Plaintiff) v. RRI Energy MidAtlantic Power Holdings et al.*, Civil Action No. 07-CV-5298 (JKG) (US District Court for the Eastern District of Pennsylvania).

## **2. Occasions where Dr. Sahu has provided Written or Oral testimony before Congress:**

- (kkk) In July 2012, provided expert written and oral testimony to the House Subcommittee on Energy and the Environment, Committee on Science, Space, and Technology at a Hearing entitled “Hitting the Ethanol Blend Wall – Examining the Science on E15.”

## **3. Occasions where Dr. Sahu has provided oral testimony at trial or in similar proceedings include the following:**

- (lll) In February, 2002, provided expert witness testimony on emissions data on behalf of Rocky Mountain Steel Mills, Inc. in Denver District Court.
- (mmm) In February 2003, provided expert witness testimony on regulatory framework and emissions calculation methodology issues on behalf of the US Department of Justice in the Ohio Edison NSR Case in the US District Court for the Southern District of Ohio.
- (nnn) In June 2003, provided expert witness testimony on regulatory framework, emissions calculation methodology, and emissions calculations on behalf of the US Department of Justice in the Illinois Power NSR Case in the US District Court for the Southern District of Illinois.
- (ooo) In August 2006, provided expert witness testimony regarding power plant emissions and BACT issues on a permit challenge (Western Greenbrier) on behalf of the Appalachian Center for the Economy and the Environment in West Virginia.
- (ppp) In May 2007, provided expert witness testimony regarding power plant emissions and BACT issues on a permit challenge (Thompson River Cogeneration) on behalf of various Montana petitioners (Citizens Awareness Network (CAN), Women's Voices for the Earth (WVE) and the Clark Fork Coalition (CFC)) before the Montana Board of Environmental Review.
- (qqq) In October 2007, provided expert witness testimony regarding power plant emissions and BACT issues on a permit challenge (Sevier Power Plant) on behalf of the Sierra Club before the Utah Air Quality Board.
- (rrr) In August 2008, provided expert witness testimony regarding power plant emissions and BACT issues on a permit challenge (Big Stone Unit II) on behalf of the Sierra Club and Clean Water before the South Dakota Board of Minerals and the Environment.
- (sss) In February 2009, provided expert witness testimony regarding power plant emissions and BACT issues on a permit challenge (Santee Cooper Pee Dee units) on behalf of the Sierra Club and the Southern Environmental Law Center before the South Carolina Board of Health and Environmental Control.
- (ttt) In February 2009, provided expert witness testimony regarding power plant emissions, BACT issues and MACT issues on a permit challenge (NRG Limestone Unit 3) on behalf of the Sierra Club and the Environmental Integrity Project before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.
- (uuu) In November 2009, provided expert witness testimony regarding power plant emissions, BACT issues and MACT issues on a permit challenge (Las Brisas Energy Center) on behalf of the Environmental Defense Fund before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.
- (vvv) In February 2010, provided expert witness testimony regarding power plant emissions, BACT issues and MACT issues on a permit challenge (White Stallion Energy Center) on behalf of the Environmental Defense Fund before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.
- (www) In September 2010 provided oral trial testimony on behalf of Commonwealth of Pennsylvania – Dept. of Environmental Protection, State of Connecticut, State of New York, State of Maryland, and State of New Jersey (Plaintiffs) in connection with the Allegheny Energy NSR Case in US District Court in the Western District of Pennsylvania. *Plaintiffs v. Allegheny Energy Inc., et al.*, 2:05cv0885 (W.D. Pennsylvania).
- (xxx) Oral Direct and Rebuttal Expert Testimony (September 2010) on behalf of Fall-Line Alliance for a Clean Environment and others in the matter of the PSD Air Permit for Plant Washington issued by Georgia DNR at the Office of State Administrative Hearing, State of Georgia (OSAH-BNR-AQ-1031707-98-WALKER).
- (yyy) Oral Testimony (September 2010) on behalf of the State of New Mexico Environment Department in the matter of Proposed Regulation 20.2.350 NMAC – *Greenhouse Gas Cap and Trade Provisions*, No. EIB 10-04 (R), to the State of New Mexico, Environmental Improvement Board.
- (zzz) Oral Testimony (October 2010) regarding mercury and total PM/PM10 emissions and other issues on a remanded permit challenge (Las Brisas Energy Center) on behalf of the Environmental Defense Fund before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.
- (aaaa) Oral Testimony (November 2010) regarding BART for PSCo Hayden, CSU Martin Drake units before the Colorado Air Quality Commission on behalf of the Coalition of Environmental Organizations.

- (bbbb) Oral Testimony (December 2010) regarding BART for TriState Craig Units, CSU Nixon Unit, and PRPA Rawhide Unit) before the Colorado Air Quality Commission on behalf of the Coalition of Environmental Organizations.
- (cccc) Deposition (December 2010) on behalf of the US Department of Justice in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana).
- (dddd) Deposition (February 2011 and January 2012) on behalf of Wild Earth Guardians in the matter of opacity exceedances and monitor downtime at the Public Service Company of Colorado (Xcel)'s Cherokee power plant. No. 09-cv-1862 (D. Colo.).
- (eeee) Oral Expert Testimony (February 2011) to the Georgia Office of State Administrative Hearings (OSAH) in the matter of Minor Source HAPs status for the proposed Longleaf Energy Associates power plant (OSAH-BNR-AQ-1115157-60-HOWELLS) on behalf of the Friends of the Chattahoochee and the Sierra Club).
- (ffff) Deposition (August 2011) on behalf of the United States in *United States of America v. Cemex, Inc.*, Civil Action No. 09-cv-00019-MSK-MEH (US District Court for the District of Colorado).
- (gggg) Deposition (July 2011) and Oral Testimony at Hearing (February 2012) on behalf of the Plaintiffs MYTAPN in the matter of Microsoft-Yes, Toxic Air Pollution-No (MYTAPN) v. State of Washington, Department of Ecology and Microsoft Corporation Columbia Data Center to the Pollution Control Hearings Board, State of Washington, Matter No. PCHB No. 10-162.
- (hhhh) Oral Testimony at Hearing (April 2012) on behalf of the New Hampshire Sierra Club at the State of New Hampshire Public Utilities Commission, Docket No. 10-261 – the 2010 Least Cost Integrated Resource Plan (LCIRP) submitted by the Public Service Company of New Hampshire (re. Merrimack Station Units 1 and 2).
- (iiii) Oral Testimony at Hearing (March 2012) on behalf of the US Department of Justice in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana).

**ATTACHMENT B – HEAT INPUT AND NOX DATA FOR COAL CREEK UNITS 1 AND 2**

Attachment B - EPA AMPD Heat Input and NOx Data for Baseline Analysis for Coal Creek Unit 1						
Year	Mo	Heat Input (HI) (MMBtu/mo or MMBtu/yr)			NOx Rate (lb/MMBtu)	
		Monthly	24-Month Annual Average	Highest Annual During 2006-2010	Monthly Average	Highest During 2010-today (post-DryFining)
2002	1	4464270			0.193	
2002	2	3326511			0.225	
2002	3	4179657			0.205	
2002	4	719068			0.207	
2002	5	3982244			0.217	
2002	6	4155036			0.216	
2002	7	4206698			0.225	
2002	8	4574418			0.211	
2002	9	4149499			0.201	
2002	10	4270719			0.204	
2002	11	4284372			0.197	
2002	12	4322165			0.217	
2003	1	4486900			0.209	
2003	2	3946579			0.210	
2003	3	4573131			0.197	
2003	4	3794806			0.195	
2003	5	4100413			0.207	
2003	6	4320176			0.195	
2003	7	4341810			0.196	
2003	8	4532202			0.184	
2003	9	4165673			0.230	
2003	10	4212368			0.220	
2003	11	4323100			0.204	
2003	12	4496129	48963971		0.203	
2004	1	4469619	48966646		0.205	
2004	2	4322403	49464591		0.211	
2004	3	4067515	49408520		0.194	
2004	4	4296112	51197042		0.213	
2004	5	3751856	51081848		0.198	
2004	6	4405496	51207079		0.214	
2004	7	4345373	51276416		0.239	
2004	8	4488812	51233614		0.228	
2004	9	4105967	51211848		0.220	
2004	10	4373739	51263358		0.231	
2004	11	4423512	51332928		0.210	
2004	12	4377372	51360531		0.236	
2005	1	4621627	51427894		0.219	
2005	2	4090630	51499920		0.229	
2005	3	2605983	50516346		0.222	
2005	4	781045	49009466		0.263	
2005	5	4602051	49260284		0.225	
2005	6	4576433	49388413		0.230	
2005	7	4643255	49539135		0.232	
2005	8	4611940	49579005		0.253	
2005	9	4294650	49643493		0.243	
2005	10	4430688	49752653		0.248	
2005	11	4130868	49656537		0.234	

2005	12	4671234	49744090	51969572	0.224	
2006	1	4541147	49779853		0.215	
2006	2	4099086	49668195		0.215	
2006	3	4536894	49902885		0.214	
2006	4	4280142	49894900		0.243	
2006	5	3653718	49845831		0.231	
2006	6	4365008	49825587		0.243	
2006	7	4513004	49909402		0.244	
2006	8	4558891	49944441		0.237	
2006	9	4259186	50021051		0.256	
2006	10	3673392	49670878		0.251	
2006	11	3995258	49456751		0.242	
2006	12	4393228	49464679		0.256	
2007	1	4335117	49321424		0.247	
2007	2	4097086	49324652		0.240	
2007	3	4366244	50204783		0.245	
2007	4	4310624	51969572		0.258	
2007	5	3869574	51603333		0.242	
2007	6	3821947	51226091		0.252	
2007	7	4258605	51033765		0.247	
2007	8	4254326	50854958		0.260	
2007	9	4091902	50753584		0.264	
2007	10	4112952	50594716		0.247	
2007	11	4150611	50604588		0.245	
2007	12	4327634	50432788		0.236	
2008	1	4323041	50323735		0.230	
2008	2	4048267	50298325		0.220	
2008	3	1935511	48997634		0.270	
2008	4		46857563			
2008	5	1651968	45856688		0.241	
2008	6	3631117	45489742		0.259	
2008	7	4631214	45548848		0.251	
2008	8	4640699	45589752		0.253	
2008	9	4316004	45618160		0.262	
2008	10	4254615	45908772		0.272	
2008	11	4201076	46011681		0.274	
2008	12	4412971	46021552		0.259	
2009	1	4375926	46041956		0.254	
2009	2	3941802	45964314		0.238	
2009	3	4441212	46001798		0.247	
2009	4	3934701	45813837		0.247	
2009	5	3337700	45547900		0.241	
2009	6	4164687	45719270		0.241	
2009	7	4249076	45714505		0.259	
2009	8	4282616	45728650		0.215	
2009	9	4012503	45688951		0.283	
2009	10	4376416	45820683		0.250	
2009	11	4205423	45848089		0.214	
2009	12	4303353	45835949		0.234	
2010	1	4176804	45762831		0.219	0.2309
2010	2	3654508	45565951		0.229	
2010	3	3854291	46525342		0.231	
2010	4	4065868	48558276		0.213	
2010	5	4147040	49805811		0.206	
2010	6	4161443	50070975		0.210	
2010	7	4256831	49883783		0.195	

2010	8	4314145	49720506		0.220
2010	9	4183844	49654426		0.207
2010	10	4031522	49542880		0.191
2010	11	4224691	49554687		0.200
2010	12	4338824	49517613		0.213
2011	1	4129466	49394383		0.215
2011	2	3732587	49289776		0.175
2011	3	4296951	49217646		0.192
2011	4	115164	47307877		0.209
2011	5	2314976	46796515		0.197
2011	6	4159462	46793903		0.193
2011	7	4379237	46858983		0.187
2011	8	3651923	46543636		0.219
2011	9	3827880	46451325		0.224
2011	10	4290947	46408590		0.213
2011	11	3818103	46214930		0.223
2011	12	4298107	46212306		0.212
2012	1	4343841	46295825		0.216
2012	2	3895175	46416159		0.216
2012	3	4052971	46515498		0.215
2012	4	3781096	46373112		0.202
2012	5	3480564	46039874		0.214
2012	6	4174518	46046411		0.190
2012	7	4297435	46066713		0.205
2012	8	4254578	46036929		0.205
2012	9	3898064	45894039		0.220

Attachment B - EPA AMPD Heat Input for Baseline Analysis for Coal Creek Unit 2				
Year	Mo	Heat Input (HI) (MMBtu/mo or MMBtu/yr)		
		Monthly	24-Month Annual Average	Highest Annual During 2006-2010
2002	1	4292197		
2002	2	3839316		
2002	3	4279425		
2002	4	4162710		
2002	5	4170502		
2002	6	4358812		
2002	7	4358586		
2002	8	4465966		
2002	9	4315958		
2002	10	4309787		
2002	11	4121860		
2002	12	3935104		
2003	1	4290000		
2003	2	3887160		
2003	3	3917393		
2003	4	4238714		
2003	5	4481915		
2003	6	4345891		
2003	7	4540368		
2003	8	4290911		
2003	9	3759772		
2003	10	4379375		
2003	11	4192832		
2003	12	4314070	50624311	
2004	1	4148838	50552631	
2004	2	3792948	50529447	
2004	3	2601340	49690404	
2004	4	1401729	48309914	
2004	5	4335527	48392427	
2004	6	4306482	48366262	
2004	7	4225108	48299523	
2004	8	4474040	48303560	
2004	9	4289832	48290497	
2004	10	4199503	48235355	
2004	11	4022327	48185589	
2004	12	4130827	48283450	
2005	1	4106929	48191915	
2005	2	3745135	48120902	
2005	3	3797668	48061040	
2005	4	4229320	48056343	
2005	5	4432786	48031778	
2005	6	3938127	47827896	
2005	7	4499492	47807458	
2005	8	4500871	47912438	
2005	9	4297317	48181210	
2005	10	4178552	48080799	
2005	11	4261642	48115204	
2005	12	4357732	48137035	

2006	1	4470800	48298016
2006	2	4096516	48449800
2006	3	4427633	49362947
2006	4	4241901	50783033
2006	5	3395335	50312936
2006	6	4323148	50321270
2006	7	4508597	50463014
2006	8	4511499	50481744
2006	9	4220954	50447305
2006	10	4270823	50482965
2006	11	4224807	50584205
2006	12	4344801	50691191
2007	1	4329014	50802234
2007	2	3905993	50882663
2007	3	2148333	50057996
2007	4	813	47943742
2007	5	3780604	47617651
2007	6	3955089	47626133
2007	7	4044598	47398685
2007	8	4325998	47311249
2007	9	4105985	47215583
2007	10	4290895	47271755
2007	11	3853577	47067722
2007	12	4417281	47097497
2008	1	4409743	47066968
2008	2	3132683	46585051
2008	3	3444494	46093482
2008	4	4279154	46112108
2008	5	4313695	46571288
2008	6	4096004	46457716
2008	7	4115729	46261282
2008	8	3801912	45906489
2008	9	3873420	45732722
2008	10	4132484	45663552
2008	11	3846005	45474152
2008	12	4264961	45434232
2009	1	3957628	45248538
2009	2	3445043	45018063
2009	3	4468554	46178174
2009	4	4307660	48331597
2009	5	2499387	47690989
2009	6	4312304	47869596
2009	7	4310950	48002773
2009	8	4242354	47960951
2009	9	3861104	47838510
2009	10	4186485	47786305
2009	11	4256954	47987994
2009	12	4372159	47965432
2010	1	4389399	47955260
2010	2	3688688	48233263
2010	3	2656644	47839338
2010	4		45699761
2010	5	1894458	44490143
2010	6	4233347	44558814
2010	7	4346022	44673961
2010	8	4303542	44924776

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2010	9	3943718	44959925	
2010	10	4301024	45044195	
2010	11	4119017	45180700	
2010	12	4122700	45109570	
2011	1	4147317	45204415	
2011	2	3898084	45430935	
2011	3	4073670	45233494	
2011	4	4133614	45146471	
2011	5	2564449	45179002	
2011	6	4149968	45097834	
2011	7	4229275	45056996	
2011	8	3886660	44879150	
2011	9	4013298	44955247	
2011	10	4170188	44947098	
2011	11	3396424	44516833	
2011	12	4279677	44470592	
2012	1	4291199	44421492	
2012	2	3840214	44497255	
2012	3	4000055	45168961	
2012	4	4012157	47175040	
2012	5	2886147	47670884	
2012	6	3831982	47470202	
2012	7	4322708	47458545	
2012	8	3962649	47288098	
2012	9	4088734	47360606	